



Procedures and Guidelines

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Title: Fiber Optic Cable Assembly Manufacturing For Spaceflight Applications

1 PURPOSE

The purpose of the procedure/guideline is to specify the minimum, general, top level requirements and recommended practices for the termination of fiber optic cables used in high reliability spaceflight applications. These requirements are the basis for detailed, lower level work instructions, although not every top level requirement will necessarily result in a lower level, formal written procedure.

2 REFERENCES

GPG 8730.3, The GSFC Quality Manual
GPG 8700.2, Design Development
NASA-STD-8739.5, Fiber Optic Terminations, Cable Assemblies, And Installation
GSFC PPL Latest Release, Preferred Parts List
MIL-T-43435, Tape, Impregnated, Lacing, and Tying
GSFC Reference Publication 1124, Outgassing Data for Selecting Spacecraft Materials
MSFC Specification 40M51284, Insulation Tubing, Poly-tetrafluorethylene Resin, Non-Rigid

3 SCOPE

The procedure/guideline is mandatory for GSFC spaceflight applications, including flight connector savers. It applies to all fiber optic cable assemblies and harnesses using simplex cables. Systems using ribbon cable and other type of assemblies (i.e., pigtailed) will have similar requirements; however, certain manufacturing guidelines will differ.

The document is highly recommended for ground support applications, balloons, sounding rockets, sub-orbital vehicles, or high fidelity spacecraft mockups where reliability is a concern. In the event of conflicting requirements, project level requirements shall take precedence, followed by this procedure/guideline, and then NASA-STD-8739.5.

The procedure/guideline applies to spaceflight components (or other items defined by a project) that fall under the GSFC Quality Management System. It covers all such activities performed by members of, and contractors working for, the GSFC Electrical Systems Branch, as well as employees and contractors of other GSFC organizations that are involved in the development of spaceflight components.

4 DEFINITIONS

- a. Cable assembly: A fiber optic cable, containing a single fiber, terminated on both ends with optical fiber connectors or termini.
- b. Harness: A collection of two or more cable assemblies arranged together into a bundle. A harness may be configured with or without common covering and with or without breakouts.
- c. Pigtail: A term used to describe an optical fiber assembled with a connector or terminus on one end only. The other end of the optical fiber is usually prepared so that it can be permanently attached to another device, item, or component. Often, an optical pigtail is lensed on the prepared end and metallized so that it can be soldered to the outer enclosure or package of another device (LED, laser, detector, transceiver, etc.).
- d. Simplex cable: A single cable assembly.
- e. Pistoning: Permanent and/or temporary movement of a bonded optical fiber relative to a connector/terminus ferrule endface. Pistoning is strongly linked to temperature cycling environments, the glass transition temperature (T_g) of the adhesive system, and connector/terminus mating forces.
- f. Back-lighting: A method of illuminating the fiber endface by launching incoherent light into the optical fiber core from the opposite end of the fiber.
- g. Optical fiber termini: Cable assembly termination components that must be inserted into a higher level housing or shell to make a fiber optic connector. The termini are often assembled into a standard military specification electrical connector. One example is a MIL-C-38999 connector with MIL-T-29504 termini.

5 AUTHORITIES AND RESPONSIBILITIES

Management shall appoint a lead fiber optic engineer and technician that have been NASA trained and certified in spaceflight fiber optics. The engineer and technician shall be responsible for ensuring that all fiber optic system requirements are met, developing detailed work instructions, problem resolution, and work order closeout/signature.

The Fiber Optic Interconnect Laboratory (FOIL), GSFC Code 565, is the focal point for spaceflight fiber optic design, manufacturing, installation, integration, and test.

NASA Training Centers shall be responsible for fiber optic training.

6. IMPLEMENTATION

Technical Rationale: Requirements in this procedure/guideline must be met to ensure the high reliability necessary for spaceflight applications. Many fiber optic cable assembly manufacturing techniques commonly used in industry for other applications (telecommunications, computer networks, etc.) are oftentimes unacceptable for spaceflight applications. Several key factors make spaceflight applications unique: lack of repair or replacement capability; severe environments (exposure to radiation, temperature cycling, shock, vibration), and restricted materials issues (outgassing, offgassing).

Components, materials, and techniques used in fiber optic cable assembly manufacturing that have not been tested or approved for spaceflight can cause system performance degradation during mission operation. Material outgassing in vacuum environments can be a serious problem for many spacecraft systems (i.e., telescopes, detector lenses, etc.). Also, space radiation can cause significant performance losses in some types of optical fiber. Nicks in glass optical fibers can result in latent defects and ultimate failure (breakage) of the fiber.

Because of these factors, each and every manufacturing step must be designed with high reliability in mind and tightly controlled. Furthermore, only those suppliers who are knowledgeable, trained/certified, and experienced in spaceflight fiber optic work can be used as component vendors.

Impact of Non-practice: Failure to select approved materials and to follow the manufacturing and inspection requirements of this procedure/guideline can result in limited initial performance and subsequent system degradation during spaceflight. Severe degradation could result in mission failure.

Benefits: This procedure/guideline helps to ensure uniform reliability practices for fiber optic cable assemblies by requiring the selection of components that have been tested and approved for spaceflight and by specifying approved manufacturing techniques which include in-process inspections.

Manufacturing as defined here is the process of terminating an optical fiber cable, or in other words, the fabrication of a cable assembly.

6.1. General

6.1.1. Requirements herein shall only be applicable to simplex cables.

Ribbon cable and other assemblies will have unique manufacturing requirements; however, they will be similar to many of those listed herein.

- 6.1.2. Environmental and performance requirements for cable assemblies shall be defined using system level spacecraft requirement documents.
- 6.1.3. Cable assemblies shall meet all performance requirements under the specified environmental conditions.
- 6.1.4. Fiber optic cable assemblies shall only be fabricated by NASA trained and certified fiber optic personnel.
- 6.1.5. A cable assembly manufacturing log shall be generated and used for documentation and traceability
- 6.1.6. A cable assembly manufacturing log shall be filled out for each cable.
- 6.1.7. A cable assembly manufacturing log shall contain all information required herein to be in the engineering documentation or work instruction.
- 6.1.8. All fiber optic cable assembly components shall have been approved for spaceflight and meet required environmental conditions, including adhesive cure oven temperatures, before manufacturing shall be started
Examples include but are not limited to: outgassing, vibration, temperature range, optical loss characteristics, etc.
- 6.1.9. Approved dust caps shall be installed on all finished cables.
- 6.1.10. Shelf life limited items shall be identified and then marked, controlled, and properly handled.
Some chemicals and materials may be limited life items (i.e., their potency or characteristics may degrade over time) and must be controlled to ensure that expired items are not used for assembly of spaceflight hardware.
- 6.1.11. Optical fiber fragments or shards shall be handled carefully and disposed of per local safety requirements.
- 6.1.12. Chemicals shall be handled carefully and disposed of per local safety requirements.
- 6.2. Temperature Cycling Pre-conditioning
Shrinkage of cable components (outer jackets, loose tubes, buffers, etc) can occur after exposure to temperature cycling. This is a GSFC “lessons learned” uncovered during performance testing. An unacceptable amount of cable shrinkage after temperature cycling resulted in an excessive optical losses. In addition to optical loss, cable shrinkage can undermine the mechanical integrity of cable assemblies if components such as jackets

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or buffers contract and pull out of connector parts. It is important to note that post manufacturing visual inspections do not always detect all potential problems.

6.2.1. Cables shall be subjected to temperature cycling pre-conditioning, before fabrication begins, per the engineering documentation or work instruction.

6.2.2. Cables shall be cut to within a determined value of their final length before temperature cycling pre-conditioning begins.

Cables do not shrink uniformly across their length. Because the ends of cables tend to shrink more than the middle, cutting off cable ends can invalidate pre-conditioning. Typically, cables should be within 4 inches of their final length when pre-conditioned (note that the 4 inch value is not universally valid for all cables and must be determined on a case by case basis).

6.2.3. Cable pre-conditioning length shall be included in the engineering documentation or work instruction.

6.2.4. Temperature cycling pre-conditioning shall be determined case-by-case depending on the cable part number, maximum/minimum temperature requirements (often storage temperatures), and maximum tolerable cable component shrinkage ranges.

6.2.5. Temperature cycling pre-conditioning requirements including temperature ranges, number of cycles, ramp rates, and dwell times shall be included in the engineering documentation or work instruction.

6.3. Adhesive/Epoxy Requirements

The proper weighting, mixing, and curing of an adhesive system is critical to a reliable product. Details regarding these important aspects are often overlooked by contractors and vendors who fabricate fiber optic cables for other applications or who are not familiar with high reliability issues.

6.3.1. Epoxy bond line temperature verification shall be made using a test probe assembly made from a thermal couple and the same connector/terminus, adhesive/epoxy being fabricated.

GSFC experience has shown that “Meat thermometers” and other general purpose probes are not acceptable for epoxy bond line temperature verification. The pot life or working life of an adhesive shall be determined as a function of temperature.

6.3.2. The engineering documentation or work instruction shall include requirements for the adhesive's shortest pot life or working life based on the maximum room temperature possible during adhesive application.

6.3.3. The glass transition temperature (T_g) of the adhesive used to bond an optical fiber to an optical connector/terminus shall be at least 10° C greater than the maximum temperature that the assembly will be subjected to, including test and storage temperatures.

The T_g of an optical fiber adhesive must be controlled to minimize optical performance variations caused by the potential movement of the bonded fiber within the optical assembly after temperature cycling. The movement of adhesively bonded optical fibers within connectors (fiber pistoning) has been strongly correlated to the adhesive's glass transition temperature (T_g). Tests have shown that optical fibers (which are adhesively bonded to a connector) move when the connector is subjected to temperatures greater than the T_g of the bonding adhesive. Fiber movement can affect optical performance and increase optical losses (by changes in fiber longitudinal position) particularly in physical contact (PC) connectors.

6.3.4. The following items shall be included in the engineering documentation or work instruction.

The detailed requirements listed below oftentimes are overlooked or omitted by experienced vendors. Requirements, which alert vendors to pitfalls in areas known to have reliability problems, are necessary.

6.3.4.1. Weighing proportions with weight tolerances. Weighing proportions and weight tolerances for multi-part adhesive systems shall ensure that the adhesive system meets all adhesive requirements, including minimum bond strength, hardness, T_g, and outgassing, after proper curing.

6.3.4.2. Number of mixing cycles or mixing time, and mixing instructions. The number of mixing cycles, mixing time and mixing instructions for multi-part adhesive systems shall provide the means to completely and uniformly mix all component parts and shall ensure that the adhesive system meets all adhesive requirements, including minimum bond strength, hardness, T_g, and outgassing, after proper curing.

6.3.4.3. Cure time and cure temperature with time and temperature tolerances (cure schedule). Variations and uncertainties due to oven cell temperature differences, thermostat switching temperatures, thermometer uncertainties, and the time for the fiber optic item and the adhesive to heat up and stabilize at the proper cure temperature shall be

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accounted for and included in the cure time and cure temperature values. The cure schedule shall ensure that the adhesive system meets all adhesive requirements, including minimum bond strength, hardness, Tg, and outgassing, after curing.

- 6.3.5. The selected adhesive cure schedule shall be compatible with the thermal limitations of the cable and connector/terminus.
- 6.3.6. The selected adhesive cure schedule shall include addition time for the time a room temperature connector/terminus takes to reach the cure temperature.
- 6.3.7. The selected adhesive cure schedule shall ensure that the final cable assembly will meet processing, testing and mission environments.
- 6.3.8. The selected adhesive cure schedule shall ensure > 98% cure.
Adhesives which are not fully cured (i.e., < 98%) may cause fiber pistoning, may result in permanent fiber movement during subsequent environmental testing, may not achieve adequate bond strength or adhesion, or may outgas. It is absolutely critical that the adhesive be fully cured. This is often overlooked or not accounted for in the cure schedule development. A one time qualification test (Differential Scanning Calorimeter, i.e., DSC) using the minimum time and temperature of the cure schedule is sufficient to satisfy this requirement.

6.4. Cleaning Materials and Solvents

- 6.4.1. Solvents used for the removal of grease, oil, dirt, films, and particles should be selected for their ability to remove both ionic and nonionic chemistries.
- 6.4.2. Solvents shall not degrade materials or parts being cleaned.
- 6.4.3. Solvent containers shall be clearly labeled with the correct name and part number of the liquid inside.
- 6.4.4. Solvent containers with flip top lids shall be used for dispensing.
- 6.4.5. Solvent containers shall be pre-conditioned for 24 hours with the solvent before first use.
- 6.4.6. Solvent used for pre-conditioning containers shall be properly disposed upon completion of pre-conditioning.
- 6.4.7. Solvents shall be identified using the exact manufacturer's part number in the engineering documentation or work instruction.
- 6.4.8. MSDS for solvents shall be posted where used.
- 6.4.9. Application of water to silica optical fiber shall be minimized.
- 6.4.10. If water is applied to silica optical fiber, thorough drying shall be accomplished immediately after completion of the process.
- 6.4.11. Solvents have the potential of causing severe damage to materials. Appropriate testing shall be performed as part of solvent evaluation for any procedure.
- 6.4.12. Low Non-Volatile Residue (NVR) wipes and swabs shall be used for cleaning.
- 6.4.13. Ink permanency and solvent compatibility testing shall be performed as part of both the ink and solvent the evaluation process.
- 6.4.14. Some adhesives can become brittle when in contact with solvents. Prior to use, the appropriate engineering activity shall verify compatibility between adhesives and solvents used for cleaning the assembly.

6.5. Parts, Materials, Equipment, Tools

Documentation of all part numbers is necessary in the engineering documentation or work instruction to provide traceability in the event of problems and to provide insight into which items work well and which do not over the long term.

- 6.5.1. Exact part numbers of all tools, materials, and equipment shall be listed in the engineering documentation or work instruction.

The listing of multiple substitute items is highly discouraged as traceability is lost. GSFC experience has shown that differences between substitute items often times cause reliability problems.

- 6.5.2. All material (cable, adhesive, connector/termini, etc.) lot numbers shall be included in the engineering documentation or work instruction.

- 6.5.3. All tools, materials, and equipment shall be checked against the engineering documentation or work instruction before fabrication begins.

- 6.5.4. Absolutely no tool, material, or equipment substitutes of those listed in the engineering documentation or work instruction shall be allowed.

- 6.5.5. All tools, materials, and equipment shall be labeled as required.

- 6.5.6. All tools, materials, and equipment shall be calibrated as required.

- 6.5.7. All tools, materials, and equipment shall be cleaned as required before use.

6.6. Cleaning

The cleanliness of all parts, which come in contact with the adhesive, is critical to a reliable bond and end product. The specific requirements listed below oftentimes are overlooked or omitted even by experienced vendors. GSFC experience has shown that many reliability problems are traceable to the lack of high standards regarding parts, material, and equipment cleanliness.

- 6.6.1. All parts, that come in contact with the adhesive, including all dispenser parts and mixing pans, as well as the fiber and connector to be bonded, shall be thoroughly cleaned with appropriate solvents before bonding.

- 6.6.2. After cleaning is performed, care shall be taken not to re-contaminate cleaned items by inadvertent contact with dirty surfaces.

6.7. Optical Fiber Cable Preparation and Stripping

The optical fiber cable outer jacket, strength member, loose tube, and fiber coating components must be properly prepared for the bonding process by stripping and subsequent cleaning

Prior to assembly, the fiber and all cable components must be subjected to an in-process inspection to ensure that there are no unacceptable conditions associated with the cable as described in the engineering documentation or work instruction. Inspections for correct stripping dimensions, potential damage, and cleanliness before bonding are required for high reliability as inspections for those items are possible after bonding.

Optical fiber coating stripping operations should be validated by testing. Sample optical fibers subjected to the stripping and cleaning processes should be tensile load tested. The tensile load test will ensure that the fiber is free from any significant damage, which could occur during stripping. The fiber can be inadvertently nicked by mechanical stripping tools, and some chemical stripping solutions may weaken the fiber.

Tensile testing of bare fibers after mechanical stripping operations, e.g., for units such as fused star couplers is important. A nick caused by mechanical stripping in the fiber near the fuse star is a serious flaw. Tensile testing of bare fiber should be considered in all first article cases to improve fiber optic component reliability.

6.7.1. Stripped Cable Dimensions

6.7.1.1. Stripping dimensions with tolerances for all cable components (optical fiber buffer/coating, strength member, loose tube, outer jacket, etc.) shall be specified in the engineering documentation or work instruction.

6.7.1.2. All cable components shall be subjected to an in-process inspection for correct stripping dimensions, prior to bonding, in accordance with defined dimensions with tolerances. Before connector/terminus bonding, an in-process inspection must be performed on the stripped cable to guarantee reliable connectorization.

6.7.1.3. In-process inspections for correct stripping dimensions shall be recorded in a cable assembly manufacturing log.

6.7.2. Potential Stripping Damage/Anomalies

6.7.2.1. All cable components shall be subjected to an in-process inspection for potential stripping damage, prior to bonding, in accordance with damage categories and acceptance criteria. Before connector/terminus bonding, an in-process inspection must be performed on the stripped cable to guarantee reliable connectorization.

6.7.2.2. Potential stripping damage categories (such as cracks, nicks, cuts, excessive chemical strip wicking) of all cable components (optical fiber buffer/coating, strength member, loose tube, outer jacket, etc.) shall be defined in engineering documentation or work instruction. As a minimum the following shall be considered:

6.7.2.2.1. Strength member damage

6.7.2.2.2. Cracks, nicks, cuts, or other damage to all cable components including the optical fiber

6.7.2.2.3. Chemical strip wicking or damage

6.7.2.2.4. Mechanical strip damage hidden by buffers stretched over the stripped interface

6.7.2.2.5. Incomplete coating removal

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6.7.2.2.6. Other potential damage to any cable component

6.7.2.3. Potential stripping damage categories shall have accept/reject criteria specified in the engineering documentation or work instruction.

6.7.2.4. In-process inspections for potential stripping damage shall be recorded in a cable assembly manufacturing log.

6.7.3. Chemical Stripping

6.7.3.1. Chemical stripping shall be the sole technique for removing optical fiber buffers/coatings (the component in immediate contact with the optical fiber cladding or cladding hermetic coating).

Even trained experienced operators can inadvertently nick fibers when mechanical stripping tools are used. Nicks in the fiber are very difficult to detect, and an undetected nick will result in a latent defect. Latent defects often result in fiber breakage that may not occur for a considerable length of time after termination. Burning off buffers and coatings causes fiber embrittlement and heat removable techniques generally are a form of mechanical stripping. GSFC experience with flight projects has shown that most current mechanical stripping techniques are not reliable. This is a “lessons learned” subject.

6.7.3.2. Chemical stripping solutions shall not remove hermetic coatings unless specifically required for unique designs.

6.7.3.3. An acceptance/qualification tensile test of first article, stripped optical fiber shall be required to ensure that the fiber meets the manufacturer’s specifications for tensile loading after stripping.

Some chemical stripping solutions may weaken an optical fiber. If the chemical solution is known in industry (published papers, etc.) to not weaken the fiber, the requirement need not be met.

6.7.3.4. The tensile test load values shall be determined from manufacturer’s specifications for the type of optical fiber being used (i.e., 100 kpsi).

6.7.3.5. All chemical stripping solutions (including acids) shall be marked, controlled, and handled as limited life items (i.e., their potency may be reduced over time) to ensure that expired chemicals are not used for assembly of spaceflight hardware.

Expired limited life items, which are used in processes, may reduce the reliability of the end product. Chemical stripping solutions often have

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volatile components, which upon evaporation over extended periods of time affect the ability of the solution to properly remove fiber coatings. Other chemicals may absorb moisture and thus affect their ability to properly remove coatings.

6.8. Terminus To Cable Bonding

Cleanliness is critical to a reliable bond and end product.

6.8.1. Once cleaned, no longer than 4 hours shall elapse before the parts are assembled.

GSFC experience with flight projects has shown that cleaned parts have stood for days in dirty environments and were re-contaminated. Bonding adhesion is greatly reduced when parts are dirty and the reliability of the assembly is degraded. This is a “lessons learned” subject.

6.8.2. Prior to assembly, all parts included with the cable assembly (connectors and associated hardware) shall be inspected to ensure that there are no unacceptable conditions associated with the connector as described in the engineering documentation or work instruction.

6.8.3. Connector/Terminus Preparation

6.8.3.1. Before connector bonding, connectors/termini shall be inspected for anomalies such as ferrule hole blockage, chips, cracks, or other defects.

6.8.3.2. Before connector bonding, all connector/terminus parts shall be thoroughly cleaned with approved solvents

6.8.4. Stripped Cable End Cleaning

6.8.4.1. Stripped cable ends to be cleaned shall be handled in a manner that will not degrade or damage the cable components.

6.8.4.2. Stripped cable ends shall be cleaned within a time frame that permits removal of all contaminants.

6.8.4.3. Manual cleaning of Stripped cable ends shall be performed using approved solvents and wipes or swabs.

6.8.4.4. Wipes or swabs shall be non-abrasive, lint free, and either soxhlet extracted, or equivalent, or low non-volatile residue.

6.8.4.5. Cleaning processes shall not degrade the optical characteristics of the termination.

6.8.4.6. Prior to use, the appropriate engineering activity shall verify compatibility between solvents used for cleaning the assembly and all materials, including epoxies.

6.8.4.7. Cleaning shall ensure removal of dirt, oil, grease, and particulate matter.

6.8.5. Adhesive/Epoxy Mixing

6.8.5.1. The number of Adhesive/Epoxy mixing cycles or mixing time shall be included in the engineering documentation or work instruction for systems having two or more component parts.

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6.8.5.2. A precision (quartz) digital count-up or count-down timer shall be used to control mixing times.

6.8.6. Cure Schedule

6.8.6.1. Cure time shall be included in the engineering documentation or work instruction.

6.8.6.2. Cure temperature with temperature tolerances shall be included in the engineering documentation or work instruction.

6.8.7. Adhesive/Epoxy Application

6.8.7.1. Adhesive systems shall be degassed (i.e., by use of a centrifuge or vacuum chamber) before they are applied to optical fibers and connectors to minimize the potential for fiber breakage due to bubbles or voids in the adhesive surrounding the fiber.

Bubbles in an adhesive are oftentimes introduced during mixing operations, and bubbles and voids in the adhesive surrounding optical fibers in connectors have been correlated to fiber breakage. Trapped air in the form of a bubble has a much different Coefficient of Thermal Expansion (CTE) than the adhesive (and fiber), and a void or bubble does not provide mechanical support for the fiber. During temperature cycling, the CTE mismatch and lack of fiber support can create stresses in the fiber, which could result in fiber breakage. The reliability of components in which optical fibers are adhesively bonded to piece parts is improved by when polymers are bubble free.

- 6.8.7.2. Application techniques shall ensure that adhesives do not spill out onto any parts of the connector/terminus that are not to be bonded.
- 6.8.7.3. Connectors/termini filled with uncured adhesive shall be degassed (i.e., by use of a centrifuge adapter) before they are applied to optical fibers and connectors to minimize the potential of bubbles or voids introduced during adhesive injection.
- 6.8.7.4. Syringe needle size and length shall be included in the engineering documentation or work instruction to control adhesive application and to ensure that internal connector mechanisms are not inadvertently filled with adhesive.
- 6.8.7.5. Syringes designed for medical applications shall not be used. Medical syringes are internally coated with silicone for ease of dispensing. Silicone can mix with the adhesive and produce an unreliable bond. Silicone contamination is extremely difficult to remove.
- 6.8.7.6. The amount of uncured excess epoxy on the connector/terminus endface shall be controlled per the engineering documentation or work instruction as it can contribute to fiber cracking during heat cure.
- 6.8.7.7. Care shall be taken not to re-contaminate cleaned syringe needles items by inadvertent contact with dirty surfaces.
- 6.8.7.8. The adhesive shall be applied before pot life or working life expiration time.

6.9. Adhesive/Epoxy Curing

- 6.9.1.1. Cure oven temperature shall be stabilized and within the required temperature range per the engineering documentation or work instruction before adhesive/epoxy curing is started.
- 6.9.1.2. Adhesive temperature shall be verified using a test probe assembly made from the connector/terminus and adhesive/epoxy under fabrication, and a approved thermal couple.
“Meat thermometers” are not acceptable for epoxy bond line temperature verification.

6.9.1.3. The following shall be recorded in a cable assembly manufacturing log for traceability in the event there should be several adhesive lots or if problems with an adhesive arise. Knowing which items were assembled with an adhesive under existing conditions will reduce risk and save time and money if problems arise.

6.9.1.3.1. Cure start and stop time

6.9.1.3.2. Cure oven temperature/epoxy bond line temperature – stabilized

6.9.1.3.3. Adhesive/epoxy lot numbers

6.9.1.3.4. Remaining pot life or working life at adhesive application time

6.9.1.3.5. Room temperature at adhesive application time

6.9.1.3.6. Room humidity at adhesive application

6.9.1.4. Adhesive surface tension alone shall not be used to hold parts together when assemblies are inserted into cure ovens.

Connectors must be held securely to the cable/fiber by crimp sleeves, shrink tube, etc. Other parts to be bonded should be held together securely by fixturing or other means not surface tension.

6.9.1.5. The optical fiber shall be protected from damage when assemblies are inserted into cure ovens.

6.9.1.6. A precision (quartz) digital count-down timer with alarm shall be used to control the cure time during the bonding process.

6.9.1.7. Heat guns & hotplates shall not be used to cure adhesives.

Heat guns are uncontrolled thermal application devices.

Temperatures associated with the guns may vary by 50 degrees C, or more, by movements as little as 1/4 inch toward or away from a part, and thus can overly stress (or under cure) assemblies without operator knowledge. Hotplates (literally a flat plate that is heated) result in non-uniform part heating (cold and hot spots). In addition, temperatures at the epoxy can be up to 15 degrees cooler than the plate temperature. This results in improperly cured adhesives, again without operator knowledge. Both hotplates and heatguns caused problems on flight projects and are now “lessons learned” subjects.

6.9.1.8. Post cure bonding inspection criteria shall be defined in engineering documentation or work instruction. As a minimum the following shall be considered

6.9.1.8.1. Strength member securely attached

6.9.1.8.2. Strength member uniformly distributed when visible

6.9.1.8.3. Minimal “dog legs” (bends oftentimes due to non-uniform shrinking of heat shrinkable tubing) at the cable/terminus interface

6.9.1.8.4. Unbroken fiber end

6.9.1.8.5. Leaked or spilled epoxy on the connector/terminus and cable

6.10. Scribing/Cleaving

6.10.1. Scribe and/or cleave tools shall be inspected under 50x minimum at least once daily for chips, cracks or dirt that will adversely affect scribing and cleaving processes.

6.10.2. Fibers shall be scribed once, and only once, before cleaving. Multiple scribe marks adversely affect cleaves.

6.10.3. When hand cleaved, the fiber shall be pulled off along its longitudinal axis and never sheared off by pushing it to the side.

6.10.4. Location of the scribe mark should be controlled.

6.11. Bonded Terminus Polishing

Bonded Connector/terminus endface polishing may be performed by hand or machine. Because of the better consistency and uniformity of machine polishing, hand polishing is discouraged. It should be noted that polishing can reduce ferrule length which in turn can affect connector mating forces and vibration performance.

Connector endface geometry is determined during the polishing process and has a significant effect on the performance of a cable assembly. The most common, high performance connector endface geometries are referred to as: physical contact (PC) and angle physical contact (APC). “Flat” or other specialized endface geometries are also sometimes used.

6.11.1. The engineering documentation or work instruction shall specify the type of connector endface geometry.

6.11.2. As a minimum for all endface geometries, the amount of fiber protrusion and the amount of fiber undercut shall be specified in the engineering documentation or work instruction.

Criteria for fiber position in the connector (even for flat polished connectors) must be defined in the engineering documentation or work instruction to ensure reliable connector optical performance on a spacecraft. Fiber protrusion above the surface of the connector ferrule, if not known and controlled, could result in fiber breakage during optical connector mating. On the other hand, fiber undercut increases the amount of optical loss.

6.11.3. All PC endface geometries shall have the following parameters with tolerances specified in the engineering documentation or work instruction.

6.11.3.1. Amount of fiber protrusion and fiber undercut relative to spherical reference (typically SH is +/- 50 nm)

6.11.3.2. Radius of Curvature (typically ROC is 15mm +/- 5mm)

6.11.3.3. Apex Offset (typically < 30 um)

6.11.3.4. Angle (APC only, typically 8 degrees +/- 1 deg)

6.11.4. An interferometer shall be used to control and measure connector/terminus endface geometry.

6.11.5. Minimum ferrule length shall be in the engineering documentation or work instruction.

6.12. Post Polish Verification

6.12.1. The connector assembly shall be inspected for excess adhesive on the fiber endface and other parts of the connector, as defined in the engineering documentation or work instruction, which could interfere with proper operation of the connector.

Excess adhesive on the connector endface can flake off over time and create contamination, which could affect optical performance. Excess adhesive on other connector parts can prevent springs and other mechanisms from operating properly or fitting properly together.

6.12.2. Visual examination of the polished, bonded terminus shall be performed to ensure that the finished termination is of high optical quality and free of unacceptable defects, such as chips, contamination, cracks, scratches, pits, or hackles.

6.12.3. A 200X minimum magnification shall be used for inspections.

Because of the high magnification, both the microscope lens and termini adapters and the polished terminus must be clean. Loose debris or dust is removed by using dry nitrogen. Care should be exercised to ensure that lenses of the microscope or the polished endface are not scratched during inspections. Cleaning before inspection should be accomplished as specified above.

6.12.4. The optical fiber shall be back-lit, using a flashlight or other relatively low intensity white light source, from the opposite end of the cable assembly without touching the fiber when inspecting a finished connector for fiber endface cracks.

Back-lighting the fiber makes cracks, which may be present in the fiber core readily detectable. If back-lighting is not used during inspections, cracks can be invisible or appear to look like a scratch. It should be noted that a cable assembly could pass insertion loss and reflectance tests and still have an undetected fiber crack.

6.12.5. Inspection sources which cast shadows are sometimes useful when inspecting fiber surfaces for scratches and other anomalies.

6.12.6. If cracks in an endface are found as a result of inspection, the assembly shall be re-terminated. Re-polishing to fix cracks in flight hardware is not allowed.

Although fiber cracks may be “polished out” or reworked, fine tails of the crack may still be present, but not visible.

- 6.12.7. The following unacceptable conditions associated with the cable assembly shall be considered as inspection criteria and contained in the engineering documentation or work instruction
- 6.12.7.1. The terminus must have a smoothly polished face and glass free of visible scratches and imperfections, which affect optical performance or reliability.
 - 6.12.7.2. No visible scratches on the terminus ceramic face.
 - 6.12.7.3. No fiber edge chips, scratches, pits, or hackles
 - 6.12.7.4. No contamination
 - 6.12.7.5. No fiber cracks or cracks anywhere in the ceramic ferrule
 - 6.12.7.6. No excess epoxy around the fiber or spots of epoxy anywhere on the ceramic face
- 6.13. Finished cable assemblies shall be subjected to performance verification testing (insertion loss, reflectance), and workmanship temperature cycling. After temperature cycling, endface geometry, insertion, and reflectance shall be re-verified.

CHANGE HISTORY LOG

Revision	Effective Date	Description of Changes
Baseline	10/06/1998	Initial Release
A	05/04/1999	Globally replaced certification log (traveler) with manufacturing log .